Agassiz (A.)

With the Compliments of the Author.

ON THE

YOUNG STAGES OF OSSEOUS FISHES.

BY ALEXANDER AGASSIZ.

II. DEVELOPMENT OF THE FLOUNDERS.

[FROM THE PROCEEDINGS OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES, VOL. XIV.]

WITH 8 PLATES.

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PAPERS READ BEFORE THE ACADEMY.

I.

ON THE YOUNG STAGES OF BONY FISHES.

By Alexander Agassiz.

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II. *Development of the Flounders.*

A young Flounder, immediately after its escape from the egg, presents no special points of difference from the embryos of other bony fishes, in a similar stage of growth. There are, however, in the earlier stages also many points in common, to which but little attention has been paid, thus far; and the study of these characters presents, from an embryological point of view, many features of special and also of more general interest. As I have already treated of the development of the tail and head (in Part I. of these Studies),* the gradual passage from a leptocardial tail, such as we find in Pl. III. fig. 1, to a so-called homocercal tail (Pl. IV. fig. 5), I will not refer to this again, beyond calling attention to the peculiar physiognomy of these young bony fishes, while in the stages (Pl. III. figs. 3–5, and Pl. IV. fig. 1) during which the heterocercal tail is so prominent a feature, and before the fins characteristic of the osseous fishes have become wholly or partially differentiated from the primitive embryonic fin-fold, which extends from the base of the head, and runs more or less parallel with the dorsal chord, round the anal extremity, back toward the anterior

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* Proceedings Am. Acad. Arts and Sciences, xiii. 117. Boston, 1877.

part to the anal opening. Their general resemblance, at this time, to the Ganoid types of older periods, and especially to the Amias of the present day, cannot be too strongly insisted upon. In the Flounders, there is usually but a single dorsal and anal fin, formed from the original embryonic fin-fold. I will only notice, in a general way, the separation of the anal and dorsal from the caudal, by the earlier appearance of the permanent fin-rays; and the more rapid growth of the caudal, during the time when, in the dorsal and anal fin, the embryonic fin-rays, which disappear with the growth of the permanent ones, are still the most prominent feature. Little by little, however, with the increase in depth of dorsal and anal (Pl. IV. figs. 2, 3, 4, 5), the separation between these and the base of the caudal becomes more abrupt; and this, accompanied by the gradual shrinking of the remnant of the embryonic fin-fold at the base of the caudal both above and below, soon brings the relations of the three principal fins of the Flounders to the proportions they bear in the adult (Pl. IV. fig. 5). In another species (Pl. IX.), I shall describe the gradual development of the anterior dorsal out of the primitive embryonic fin-fold. In the bony fishes, neither the development of the ventrals nor the pectorals has yet been traced from a lateral embryonic fin-fold; but, in sharks and skates, the case is different. (See J. Wyman,* in his development of Raja.)

We may perhaps find hereafter, in the development of such forms as Lumpus, Liparis, and the like, a nearer approach to the Selachian mode of development of the paired fin-rays. In those of the bony fishes the development of which I have had an opportunity of following, the pectorals are well developed; early assuming, even while in the egg, the Ganoid (Crossopterygian) type, to which I have already alluded in the first part of this paper.† In some of the earlier stages, the lateral embryonic fold, from which the pectorals are formed, can be distinctly traced, — though never assuming the great prominence which it has in the dorsal or anal embryonic folds, the paired fins early concealing the lateral folds; while it is the reverse with the dorsal and anal folds, from which the dorsal and anal fins are developed late.

The ventrals, on the contrary (Pl. VI. fig. 5, Pl. VII. fig. 4, Pl. IX. fig. 6), make their appearance very much later, and, in our Flounders, at

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* Wyman, Jeffries. Observations on the Development of Raja Batis, in Mem. Am. Acad. Boston, 1864. And also Balfour, F. M. Elasmobranch Fishes.

† Agassiz, Alexander. On the Young Stages of Osseous Fishes. Proc. Am. Acad. xiii. Boston, 1877.

first as a mere swelling of the median line, behind the hyoid bone; this (Pl. IV. figs. 3–5) grows quite rapidly; the permanent fin-rays at once make their appearance, — the anterior ones (the outer) first; and there is nothing special to note in the further development of the ventrals, which soon resemble, on a small scale, the ventrals of the adult. The ventrals possess, at no time, embryonic fin-rays, like those of the dorsal, anal, and caudal fins, formed from the longitudinal embryonic fin-fold. In the pectorals, embryonic fin-rays also precede the formation of the permanent rays; but in many bony fishes (Pl. VI. fig. 5, Pl. X. fig. 1), these permanent rays appear very early, — before those of other paired or unpaired fins, — the Crossopterygian stage being passed while still in the egg.

A striking characteristic of the young of all bony fishes is the extraordinary development of the pigment cells (chromatophores and chromatoblasts), and the great changes they undergo during the growth of the embryo. Pouchet* has more recently called attention to the wide-spread existence of these pigment spots, so well known to all students of Invertebrates. He studied them especially among the Fishes, in connection with the atrophism of the color on the blind sides of Flounders; pointing most plainly to the partial atrophy of the great sympathetic nerve, effected during the passage of the eye from the right to the left, or *vice versa*, as the cause. The power of the nervous system over the complicated system of pigment spots, which produces eventually the coloring of the adult fish, is of course much more readily traced in the younger stages, while the individual cells are still isolated, and before their anastomoses have become so complicated that it is well-nigh impossible, even in quite young specimens, to follow the changes resulting from any special nervous excitement. Compare, for instance, the simple chromatic system of cells of Pl. II. figs. 1–4, with the more and more complex anastomosing branches of Pl. III. figs. 5 and Pl. IV. figs. 1–5. This is still better seen, perhaps, if we compare Pl. VI. figs. 1–3 (young Flounders, just hatched from the egg, and a couple of days old) with Pl. VI. figs. 5–7, showing the gradual passage of the few, large, well-individualized chromatic cells of Pl. VI. fig. 3, into the innumerable system of small cells, closely packed and crowded in spots, so as to form the special design characteristic of this species.†

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* Pouchet, G. Des Changements de Coloration sous l'Influence des Nerfs. Archives de Physiologie et d'Anatomie. 1876.

† Pouchet has succeeded in producing a white side in trouts, by destroying the eye of that side. Rev. Scient. xiii. 1877.

The young Flounder has already attained a considerable size, before any signs appear of the change in the position of the eye on the left side (see Pl. III. figs. 3–5 and Pl. IV. fig. 1), and before the young fish shows the least tendency to favor one side over the other. Not until the young fish is fully three-eighths of an inch in length can the first slight difference be perceived in the position of the two eyes (when seen from above), the left eye being somewhat in advance of the other. In this species, the Flounder eventually lies down on the left side, which becomes colorless. In order to prevent repetitions, we shall call this the case of a right Flounder (dextral), — that is, of a Flounder colorless on the left side, and where the left eye has passed over to the right side, — calling the sides, at the same time, either blind or white, and the opposite ocular or colored.

Plates III. and IV. show very well the changes of form through which the young dextral Flounder passes before it finally assumes the appearance of the adult, and habitually rests with its colorless side upon the ground. All young Flounders, even long after they have all the characteristics of the adult, very frequently swim vertically for quite a length of time, or else swim near the surface, with the undulating movement they have when swimming over the bottom, their heads well raised, and bodies carried flat, parallel to the surface. Even quite old Flounders sometimes are caught swimming near the top of the water. Almost all the stages figured in Plates III. and IV. were caught near the surface, swimming vertically, like any other young bony fishes; but this they do only when they come up to feed, while the water is very smooth, about ten in the morning, on very bright sunny days, when they may be seen eagerly devouring swarms of embryo Crustaceans, of all orders. The young of other fishes seem to share this habit; for of the latter I have examined no less than twenty-five species, caught at various times with a hand-net, swimming near the surface of the water, on bright sunny days, when not a ripple ruffled the sea. With the least movement, all the more delicate of these embryos vanish; leaving only the older and more vigorous, which in their turn disappear, and seek shelter in deeper water. Only when the young fishes are old enough to be recognized as the young of their tribes, do they venture to join them in their ordinary haunts.

Pl. V. figs. 7–11, Pl. VI., and Pl. VII., on the other hand, give us in general the changes of form a young sinistral Flounder undergoes from the time it leaves the egg until it assumes the characteristics of the adult. The explanation of the plate will give all the necessary details of the changes, which are mere repetitions of those described

in Pls. III. and IV.; with the exception, of course, that the blind, colorless side is now found on the right side of the fish, the left side being the chromatic side. This species, as compared with the dextral species, is remarkable for the greater development of the pigment cells, figured on Pls. III. and IV. The young Flounder (Pl. VI. fig. 7), when not more than three-fourths inches long, is already quite opaque, the whole colored side being thickly covered with minute pigment cells: they extend also upon the dorsal and anal, in irregular blotches, forming only in later stages the patterns which characterize some of the species among our Flounders. It is not uncommon for a peculiar pattern to appear quite early (see Pls. VII. and IX.).

In the present species, the pigments of the dorsal and anal do not appear before the stage figured on Pl. VI. fig. 5.

As will be seen, on an examination of the figures of Pl. VI., the earlier stages (Figs. 1–5) are readily recognized by the total absence of pigment cells in the extremity of the caudal. This feature still persists, in quite well-advanced individuals (Pl. VI. figs. 6, 7, 8). The tail, in this species, passes rapidly through the heterocercal stages, and does not present the striking external resemblance to that of Ganoids, so characteristic of the species figured in Pls. III. and IV.

On Pl. V., additional details have been given of the mode of transfer of the eye from the one side to the other, — either the right eye to the left side, or *vice versa*, — which, with the figures of the embryos, on Pls. III., IV., VI., will show very clearly how the transfer is accomplished, in the ordinary case of a dextral or sinistral Flounder.

While still in the egg (Pl. V. fig. 6), and for some time after hatching (Pl. V. figs. 1, 2, 7, Pl. III., Pl. IV. fig. 1, Pl. VI. figs. 1–4), the eyes of the two sides are placed symmetrically on each side of the longitudinal axis. The first change — and the process is identical, whether we take a right or a left Flounder — is the slight advance towards the snout (Pl. V. fig. 3) of the eye about to be transferred; so that the transverse axis, passing through the pupil of the eyes, no longer makes a right angle with the longitudinal axis. This movement of translation is soon followed by a slight movement of rotation; so that, when the young fish is seen in profile, the eyes of the two sides no longer appear in the same plane, — that on the blind side being now slightly above and in advance of that on the colored side (Pl. IV. fig. 2, Pl. V. fig. 5, Pl. VI. fig. 5, Pl. IX. fig. 7). With increasing age, the eye on the blind side rises higher and higher towards the median longitudinal line of the head; a larger and larger part of this eye becoming visible from the colored side, where the

embryo is seen in profile (see Pl. IV. figs. 3–5, Pl. VI. figs. 6, 7, Pl. V. figs. 8–12, Pl. VII. fig. 5), until the eye of the blind side has, for all practical purposes, passed over to the colored side (Pl. V. figs. 4, 11).

The rapidity and extent of this translation and rotation of the eye from the blind to the colored side can be best seen on comparing the profiles of the heads (Pl. V. figs. 5, 10) of a dextral and a sinistral Flounder with the profiles seen from the colored sides, before the eyes have begun their movement (Pl. I., Pl. VI. fig. 6, Pl. VII. fig. 5).

As the dorsal, little by little, with advancing age, extends along the head towards the nostrils, it soon, in old specimens, finds its way behind the eye which has come from the blind side (compare the position of the anterior part of the dorsal, in Pl. VI. figs. 5 and 7, in Pl. IV. figs. 2 and 5, and Pl. VIII. fig. 3). This continued advance of the dorsal anteriorly, after the eye has passed to the colored side, naturally gave rise to a great many theories respecting the passage of the eye through the head, under the anterior part of the dorsal fin; and many naturalists, after an examination of the twisted facial part of the skull on the adult, have attempted most ingenious explanations of the mode by which the eye reached its ultimate position.

The facts contained in this paper leave no doubt that, at any rate, in the majority of the Flounders of our coast (I have traced the development of eight species), the transfer of the eye from the blind side to the color side occurs very early in life, while all the facial bones of the skull are still cartilaginous, and that long before their ossification the eye has been transferred, by a combined process of translation and rotation, to the colored side. Let x, y, z be rectangular axes; and, if we call the longitudinal axis of the body twisting x, the transverse axis at the extremity of which the eyes are placed in the plane xy, the first change taking place is that x is no longer at right angles with y, though the eyes are still in plane xy. The next change is that the plane in which the eyes are now placed ($x'y'$) makes an angle with the xy; cutting z at a slight distance above the origin of the coordinate axes, the eye of the colored side forming the apex of the angle. This angle gradually increases, until it passes beyond the plane yz, when the eye from the blind side has reached the colored side.

The subsequent modifications of the frontal bone, owing to the aberrant position of the eye from the colorless side, are interesting on account of their connection with abnormal anatomical features found in the Flounders; but they explain in no wise the mode in which the transfer of the eyes has taken place, this being anterior to any essential changes in the frontal bone. In early life, the strong muscles which

control the motion of the eyeball in the young Flounder maintain also a very powerful strain upon the frontal bone while still cartilaginous and readily flexible, and no doubt help to twist it in accordance with the gradual change in the position of the eyes.

While the observations of Malm on the young stages of Flounders tended to show the improbability of the eye passing through the skull from the blind side to the binocular, the observations of Steenstrup on the genus Plagusia, seemed, for that genus, at any rate, to show clearly that the eye did pass through the tissues of the head, during its transfer from the blind to the binocular side. But neither Malm nor Steenstrup, nor subsequently Schiödte, actually traced the changes undergone during the process. Steenstrup's specimens were alcoholic; and, although his theory was substantiated by observations on a number of intermediate stages of the passage of the eye through the tissue, yet, on the other hand, the observations of Malm, making it probable that the eye merely went round the head, in a manner not yet explained, were equally precise. I had myself traced quite a number of Flounders, in all of which the eye was transferred in accordance with the process described in the commencement of this paper, and figured on Pls. III.–VIII., — a process completely in accordance with the suppositions of Malm, and in direct contradiction to the theory of Steenstrup. In the late summer of 1875, however, I traced to my satisfaction the development of a very transparent Flounder (Pl. X. fig. 1), — so transparent, indeed, as to rival the most watery of Jelly Fishes. When placed in a flat glass dish, it could only be distinguished by allowing the light to strike it in certain directions: otherwise, all that was visible were the two apparently disembodied bright emerald eyes, moving more or less actively.

In this Flounder (Pl. X. fig. 1), already of a considerable size, — over an inch in length, — the position of the eyes was perfectly symmetrical. They were placed also at considerable distance from the anterior extremity of the snout; so that, judging from the size of the fish and the position of the eyes, as well as from the extension of the dorsal almost to the nostrils, I inferred that I had a new Flounder, in which the eyes would probably always remain more or less symmetrical, and in which the transfer of the eye from one side to the other was replaced by the exceeding transparency of the body, allowing either eye, owing to the great range of motion of the eyes both in a vertical and horizontal direction, — a feature characteristic of all Flounders, — to be really useful on both sides of the body. A Flounder can move his pupil vertically and horizontally through an

angle of at least one hundred and eighty degrees. Thus, our transparent Flounder, which I did not at first recognize as the Plagusia of Steenstrup, could readily, by looking obliquely, see with great distinctness, through the transparent tissues, what was passing on the opposite side of the body.

I made all preparations to watch the changes in this interesting fish, should any such take place; and, a couple of days afterwards, I noticed the first change in the position of the eye (Pl. X. fig. 3) of the right side. No less than fifteen of these transparent Flounders were caught at the surface, with the hand-net, at the mouth of the harbor of Newport, close to the shore, on a very quiet and brilliant morning. They were then swimming vertically, and rushing violently after the minute Entomostraca swarming on the surface; but, as soon as they were confined in shallow glass jars, they turned on the right side, where they would often remain immovable on the bottom for hours. They were rapid in their movements when disturbed; frequently jumping out of the water and over the sides of the dishes, to a considerable distance. Though they appear so delicate, they do not seem to suffer, any more than other Flounders, from their momentary stay on dry land. When swimming vertically, they usually move obliquely, the tail kept much lower than the head; and, when seen endways, are more or less curved, owing to the extreme tenuity of their body (Pl. X. fig. 2).

During the change of the eye from the blind to the binocular side of the body, the outline of the young fish becomes more rounded anteriorly; and the minute, dotlike yellow and black pigment spots, hardly perceptible in Fig. 1, Pl. X., form somewhat more prominent patches on the sides of the body, and radiating lines parallel to the fin-rays on the dorsal and anal fins (Pl. X. fig. 11).

The right eye (Pl. X. fig. 3) could, when the fish was in profile, be seen through the head slightly in advance, and somewhat above the left eye; the right eye in that position, owing to the great transparency of the body, being quite as useful as if it had been placed on the left side. In the following stages, the right eye rises gradually more and more above the left eye, in a somewhat oblique direction towards the fifth or sixth anterior ray of the dorsal, until the fifth or sixth day, when the right eye can be seen entirely clear of the left eye, well above it (Pl. X. fig. 4). Owing to the great size of the orbit, the left eye, when seen from the left side (Pl. X. fig. 3), sometimes appears shot a little behind the right, especially after the motion of rotation has commenced; for we find that in this Flounder, as well as in the others, the transfer of the

eye from the right side to the left takes place by means of a movement of translation, accompanied and supplemented by a movement of rotation over the frontal bone. But, in this case, very special conditions attend the transfer, which, at first sight, seem to make the passage of the eyes of this species an exceptional one. I think we can easily show that the present mode of transfer does not differ so radically as would at first seem from the conditions described in the other species, in the beginning of this paper. When the right eye of the young Flounder has reached the frontal bone, and approaches the base of the dorsal, we find, on turning the fish on his left side, that the right eye is no longer on the outer surface of the right side. It no longer occupies, as in the earliest stages, a huge orbit, capable of extensive movements in all directions; but unlike the left eye, which has retained all its former powers of locomotion, as well as its original place, it has gradually sunk deep into the tissues of the base of the dorsal fin, between it and the frontal, — having sunk, indeed, to such an extent that the huge orbit, so characteristic of all Flounders, has gradually become reduced to a mere circular opening. Through this opening, the eye now communicates with the exterior; while, from its position above the frontal (Pl. X. fig. 4), it has, when the pupil turns to the opposite direction, a perfectly unobstructed vision through the transparent left side of the body. Little by little, the opening on the right becomes smaller and smaller; and as, at the same time, the eye pushes its way deeper into the tissues, an additional opening is now formed on the left side (Pl. X. fig. 7), through which the right eye can now communicate directly with the left exterior on the left side of the body. Thus, in the stage intermediate between Pl. X. fig. 4 and Pl. X. fig. 8, we find no less than three orbital openings: one large one, — the original one of the left eye; a smaller one, on the left side also, the new orbit formed for the right eye, as it has pushed its way through the tissues of the base of the dorsal fin; and a small orbit on the right side, the remnant of the original right orbit of the right eye, which, before the right eye has completely passed over to the left side, becomes entirely closed (Pl. X. fig. 8). With the continued sinking of the right eye, the gradual resorption of the tissues, and the closing up of the old orbit, as the eye works its way across the head, we eventually get the right eye entirely over to the left side. It has now, by a movement of translation and of rotation, penetrated through the tissues between the base of the dorsal fin and the frontal bone; having apparently passed through the head, as was suggested to Steenstrup, by his examination of the alcoholic speci-

mens which furnished him the materials for his paper on Plagusia. The present transparent species evidently belonged to this genus (Plagusia); and I had thus succeeded in actually tracing, in one and the same individual, the passage of the right eye to the left side through the head.

If we now compare this method of transfer of the eye through the head with the transfer previously described round the frontal bone on the exterior of the head, we can readily see that the difference is not as great as it would appear at first sight. Were we to imagine this species of Plagusia with a dorsal, stopping in the anterior median line behind the posterior edge of the eyes, the transfer would then take place exactly as in the case of the common Flounders. The right eye would travel round the frontal, without having to sink into the tissues; and, if subsequently to the transfer of the right eye to the binocular side, the anterior portion of the dorsal were to extend in advance of the anterior edge of the eyes to the intermaxillary, we should then obtain a result identical with that described before, and one which actually occurs in precisely this manner as we have seen in a number of Flounders; and the mere resorption of the tissues at the base of the anterior part of the dorsal, while interesting as a short-cut to an end, is not of so great physiological value, or so important as a difference in the method of the transfer of the eye, as appears on a first examination.

Owing to the transparency of this Plagusia, several interesting structural details could readily be followed, which only tedious manipulation would have demonstrated in the other more opaque species, of which the development is here given. Among these were the great length of the optic nerve, which allows, as it were, sufficient slack to be taken in during the transfer of the eye from the right to the left side (Pl. X. figs. 4, 8, 9), so as apparently not to interfere in any way with the sight of the right eye; also, the immense accumulation of muscular bands forming the sheath of the orbits of the eyes, and providing for the great variety and range in the movements of the eyeball and lids (Pl. X. figs. 3, 4, 5, 8, 9); also the direct and very active circulation taking place to and from the heart with the cavity of the orbit of the eyes. (See Pl. X. fig. 9, where the direction of the arrows shows the course of this current.) The presence of this circulation of a so-called ocular heart can be readily traced in the adult of our Halibut.

The Flounders have thus far only been found in the most recent geological deposits: they seem to belong peculiarly to the present period. It is certainly remarkable that no Flounders should have

been discovered among the true bony fishes, which date back as far as the Jurassic Period. To whatever cause we may ascribe the peculiar development of the Flounders, it seems to have been inactive during the periods immediately preceding our own; and, in the absence of any plausible explanation of their appearance and development during the present period, we must look to some exceedingly subtle agency, of which we have at present no conception. The causes usually assigned for the development of fishes with a binocular side are all unsatisfactory; and all are invalidated by the fact that similar conditions constantly fail to produce like results. The Flounders are usually said, for instance, to rest on one side, because the great width of the body makes it the most natural position; but there are many other fishes of far greater width which always swim vertically, and never show any tendency to assume the pleuronect mode of locomotion. In fact, the great development of the dorsal and ventral fins gives to Flounders special advantages over other fishes for maintaining a vertical position. The young Flounder also shows a tendency thus to rest on one side, at a time when the young fish is much like any other fish, long before the habit could be of any special benefit or use.

The absence of a swimming-bladder has also been assigned as a principal cause of the peculiar mode of locomotion among Flounders. But there is one of our Flounders in which a swimming-bladder is already well developed in the young fish; and this does not prevent that particular species from adopting, as early as the others, the Flounder mode of locomotion.

The only other cause we can assign is that broad fishes, like the Flounders, find it of course much easier to pursue their prey, if, while swimming close to the bottom, they are protected from detection by a complicated system of pigment cells, for producing colors or patterns within certain limits, so as to resemble sand, mud, or gravel. This would gradually lead to the exclusive use of one side (should the fish lie on either side), and would result in the atrophy of the eye, unless the fish were able to transfer his eye to the other side, and thus retain it; when, as a secondary cause from this, the atrophy of the pigment cells of one side would follow. If this, however, is the natural explanation, why do not we find Flounders in almost all families of fishes, — at least, among the broad forms of the group, — and why were they not as common in earlier times as at the present day? We have also to face a very interesting point of heredity. It would certainly seem far simpler for the Flounders to hand down, from generation to generation, the two eyes on one side of the body, and

further to hatch their young, as other fishes do, with the characters of the adult; instead of leaving for a future period (and a period of great mortality among them) the development of the transfer of the eyes to the right or left, — thus transmitting merely the tendency, and not the thing itself, as we find to be the case in Acalephs (Hybocodon), in the Tunicates, Salpæ, in the Gasteropods, in the Polyzoa, &c. Yet this tendency is very well defined; for we rarely meet with dextral forms when the Flounder is sinistral, or *vice versa;* and I have, in our common Flounders, met with no instances of reversal in the course of the development. In Plagusia only did I notice such a reversal, where there was an attempt made in many cases — seven out of fifteen cases — by the young fish to force the left eye to pass to the right side by lying down on the left, but in no case did this prove successful; and, after a while, the young fish showed traces of brain disease, and soon died, usually before the process of transfer of the eye had made much progress, — showing that a violation of the normal mode of transfer cannot readily be made with impunity. This may be the explanation of the rarity of such abnormal cases in the whole family.

The attempts which I made, both in Plagusia and several of the other species of Flounders, to prevent the transfer of the eye by placing the glass dish at a height over a table, and thus allowing the light to come from below, as well as from all other sides, failed in arresting the transfer. This experiment, likewise, produced no effect in retaining the pigment spots of the blind side longer than in specimens struck by the light only normally, from above.

The habits of young Flounders differ greatly from those of the adult: while the latter are generally more or less sluggish, the young Flounders, when measuring less than a couple of inches in length, are remarkably active, bounding through the water, as it were, and, if disturbed, frequently jumping out of the flat dishes in which I kept them. When this happened, falling from the table to the floor, they often remained a considerable time out of water, without appearing to suffer from their exposure, on being put back into water.

Giard has, in the Rev. des Scienc. Nat. for September, 1877, suggested that the fundamental cause of asymmetry in the animal kingdom was due to a difference in the strength of the organs of sense; and he has given, in support of this view, some most ingenious speculations on the asymmetry of Ascidians, of which the Tadpole was transparent, while opaque Tadpoles belonged to symmetrical types; the position of asymmetrical Ascidians being determined by

that of the organs of sense of the embryos. We might add here, in favor of this view, the asymmetricals of many Acalephs (Hybocodon), in which the disproportion of one of the organs of sense (tentacles) is very great. He further calls attention to the facts that, in Pteropods, it is the organs of sense which first show asymmetry, and suggests that cyclopism has been an indirect cause of restoration of symmetry; though this point does not seem well taken, — judging, at least, by what we know of the development of cyclopism among Crustacea. At any rate, the action of light upon organs of sense, which in all embryos are developed out of all proportion to their ultimate conditions, must remain an all-important element in its effect upon the nervous system. In embryos so transparent as many young fishes, which seem to be nothing but eyes, brain, and notochord, the action of light must be infinitely more potent upon the nervous system than it can possibly be in older stages, when the muscular system has obtained a so much greater preponderance. The sensitiveness of young fishes to the slightest disturbance of the water, either as a shock or from light, is exceedingly acute; while, when older, they are apparently insensible to the same causes.

I have nothing to add to the explanation of the mechanism of coloration given by Pouchet in his admirable memoir on the change of coloration, to which I have already referred. A recapitulation of the important points may, however, help the reader not familiar with his memoir to understand the changes taking place during the development of our young Flounders. In the coloration of fishes, we must distinguish colors due to interference of light produced by the presence of thin plates, and those due to anatomical elements frequently highly colored, and endowed with sarcodic movements capable of marked changes of form, under special influences, so as to present the shape of extended dendritic surfaces or minute spherical masses through which the pigment is distributed. The changes of coloration due to thin plates are, of course, exceedingly variable, the tints following each other with great rapidity, according to the angle at which we view them. Such lamellar coloration is common among insects, crustacea, and also in some families of fishes. Among the most beautiful examples are those of the dolphin (*Coryphæna*) and of Saphirina; while the second class of colors — those due to the movements of the anatomical elements — are directly connected with the impressions of color received by the eye, and brought about by the reflex action of the nervous system. That this is the case, the rapid change of coloration produced by placing Flounders upon differently colored bottoms sufficiently proves. This

has, of course, a direct bearing upon the question of mimicry; but it must be frankly stated that, as far as the causes of coloration among animals have been studied, it is difficult to see how natural selection can have been a factor in producing permanent mimicry; while the rapidity with which many fishes adapt themselves to the color of the bottom upon which they live enables them undoubtedly to produce a protective coloration, which is of advantage to them; and constant habit may develop unequally the capacity of producing certain tints, or patterns even, which in their turn may be transmitted, and thus readily account for the lighter coloring of Flounders living upon sandy bottoms, as compared with those living upon rocky bottoms covered with dark algæ. Yet place the latter upon a light ground and the former upon a dark ground, and they will very soon adopt the proper coloration of their bottom, showing they have not lost their power of changing. As for many of the patterns of coloration of birds and in insects, produced by physical causes, it seems quite impossible to look upon them as the fortuitous product of the action of light, or to regard it as an efficient cause of protective mimicry.

The pigment cells appear early in the egg. In some of the fishes, we have even two color elements in the older stages, immediately before the young fish is hatched, — viz., the black and yellow; but, in the majority of cases, the black alone is present, the yellow element appearing subsequently, and, last of all, the red. The experiments made by Pouchet on pigment elements show that the blue pigments are probably only a dimorphic condition of the red pigments. This would give a ready explanation why Lobsters turn red when cooked, and of the blue Lobsters which are occasionally caught. The same may also be said of green. Violet pigment, which is found in some Crustacea, gives special reactions.

The anatomical elements containing the pigment are greatly changed during growth. The examination of the pigment spots of the youngest fish on any of the Plates here given with more advanced stages shows how great is the capacity for expansion in the black pigment elements, which from mere dots have almost become special organs capable of great expansion and contraction. Pouchet calls the pigment elements chromatoblasts in their embryonic condition, to distinguish them from the chromatophores into which they eventually develop. In addition to the chromatoblasts and chromatophores, Pouchet has also called attention to a third set of bodies, which he calls iridocytes. These are found in Fishes, Reptiles, Mollusks: they are situated near the surface of the integument, and produce the phenomena of iridescence

of cerulescence by interference of light (as shown by Brücke), of solid particles more or less analogous to excessively thin laminae. By simple combinations of the action of the red, yellow, and black chromatophores with the iridocytes are obtained all the colors which we can produce in Fishes, Reptiles, Crustacea, Mollusks, &c.: these colors resulting mainly from the expansion near the surface, or retraction into an inferior layer of the black chromatophore, which, thus mixed with the yellow and red, or with the iridocytes, at greater or less depths, suffice to produce all the variations of coloring of our young Flounders. An examination of Plate VIII., showing the changes of coloring produced upon young Flounders when placed upon differently colored bottoms, will readily show the process by which the different colorations are produced.

In the Flounders, after the eyes have passed to one side, the connection between the impression produced on the retina and the blind side becomes less and less distinct, until eventually a complete paralysis of the nerves affecting the chromatophores takes place; and little by little the blind side thus becomes white with advancing age.

The pigment cells are of three colors, — black, yellow, and red (Pl. VIII. fig. 6): the black expand nearest the surface, the yellow and red varying greatly in their position, according to the species. The black cells are all more or less dendritic when expanded, concentrating to a mere dot when wholly contracted. The proper mixture of the three colors in various degrees of expansion or contraction, combined with the suitable pattern of position, enables the Flounders to imitate so admirably the general effect of the ground upon which they are accustomed to feed, be it either sandy, gravelly, or muddy. So true is this, that often only a most practised eye could detect them, as, with the head slightly raised, the eyes starting out of their sockets far above the surface of the head, they turn actively in all directions, seeking for prey, or trying to escape the notice of their enemies. The rapidity with which they produce this change of color is quite striking; and, although it was well known that many fishes had the power to change gradually the tint of the body, it had not been noticed that it could be effected rapidly, and apparently at will, before it was recognized by Pouchet. I have not unfrequently removed the jar containing a young Flounder (Pl. VIII. fig. 2) from a surface imitating a sandy bottom to one of a dark chocolate color, and in less than ten minutes I have seen the black pigments obtain such a preponderance (Pl. VIII. fig. 1) that it would hardly have been possible to recognize in the dark, almost black fish the young Flounder, whose yellowish-gray speckled

hue had so well simulated sand, a few moments before. On removing him to a gravelly bottom, the spots of the side quickly became prominent (Pl. VIII. fig. 3). During all this time, the pigments of the blind side showed no trace of any sensitiveness; while, if these experiments are made when the eyes are still on both sides, the pigments of the two sides change at the same time in a corresponding manner.

It is well known that Squids and Cuttle Fish, provided as they are with exceedingly sensitive chromatic cells, are also able to imitate, for their protection and disguise, the coloring of the ground upon which they happen to live. But, in Cephalopods, the change of color of these chromatophores is more intimately connected with the nervous system, and appears far more sensitive and less subject to control than among fishes. In Cephalopods, the mere act of moving the mantle, of breathing, or of forcing the water through the siphon, seems sufficient to produce a change of tint; and a sudden disturbance is as likely to bring about a detrimental as a beneficial change of color.*

Among Fishes, Reptiles, and other Vertebrates, as well as among Cephalopods, and the mass of Mollusks, Crustacea, Annellids, Echinoderms, &c., in which we find dermal pigment cells, we can readily imagine how the effect of environments might, by reflex action, bring about a resemblance to surrounding coloring, as has been described by Pouchet and by Bert, thus producing general effects in the pigment cells, which would assimilate within certain limits with the surrounding tone. In all these cases, the explanation based upon mimicry as beneficial presents little difficulty; and we might suppose that by the laws of heredity those colors alone which had been stimulated by continued action through many generations would be transmitted. Thus Flounders, for instance, living on sandy bottom, in which the grayish tint imitating sand had been most constantly produced by the action of the proper pig-

* See the papers on the chromatophores of Cephalopods, by Hubrecht, Niederland. Archiv f. Zool., II. No. 3, p. 8, Mai, 1875, in which he makes a most interesting comparison of the phenomena of chromatophores and protoplasmic action. Also an important paper by Dr. Hagen, in the American Naturalist, vol. vi., July, 1872, on mimicry in the color of insects. The general results of Dr. Hagen's study of the phenomena of color in insects agree, in the main, with the results obtained by Pouchet from the study of Fishes, Crustacea, and Mollusks; both Pouchet and Hagen recognizing the presence of colors due to action of light, and the presence of colors due to pigments, the hypodermal and dermal layers. Judging from the interesting discussions brought out by the papers of Weismann, of Wallace, and others, on the causes of color in the animal kingdom, we are, however, only on the threshold of a most interesting and novel field of inquiry.

ment cells, would naturally transmit to their progeny in the greatest quantity only such pigment as would most easily reproduce the imitation of sand, while the same might be true of the Flounders living on muddy or gravelly bottoms. Something analogous exists in the common Echini, where dark-green and violet pigment spots closely imitate dark granitic rocks covered with seaweeds; or in the imitation of sand by the grayish-green tint of Mellita and the yellow tint of Amphidetus, &c.: yet the whole theory of mimicry, even in these cases, as a means of protection, is again overthrown by the mass of Clypeastroids, Spatangoids, Echinoids, whose dark coloring, but for their habit of burrowing in the sand in which they live, would make them most prominent objects. We next have the legions of Ctenophoræ, Jelly Fishes, and of other pelagic animals (especially the embryos) so transparent as to be scarcely distinguishable from the water in which they live, many of them are reduced to the merest film. Have they all, little by little, assumed their transparency, in order to escape their enemies? Then why do they swarm in such quantities that their numbers counteract the very object of their transparency? It is common along the seashore, at proper times of tide and wind, to find long lines where all these delicate and transparent animals are accumulated on purpose as it were to provide the food needed by their enemies, who are at hand playing sad havoc among them. Many of the embryos of our common marine animals are gregarious for a short period of their life; for instance, the young of the majority of our Crabs and Shrimps, of many Gasteropods, Annellids, and Radiates, just at the time when they are most delicate, and least capable of escaping the attacks of their enemies. At the time of hatching of the young Prawns (*Palæmonetes vulgaris*), and of the young of our Cancer, sea perch may be seen devouring them by the wholesale while they are swarming close to the shore. Thus, numberless young are destroyed in spite of their transparency, and the same holds good for a host of other embryos.

In the Flounders, we seem to have fair evidence that they are able to produce certain effects in consequence of impressions received upon the retina, and that the changes taking place on the chromatic side of the body are probably due to the capacity of the fish to distinguish certain colors from others. But more accurate experiments than I have yet made are necessary to enable us to decide whether the sense of color is developed so early in the Vertebrate series, or whether we have simply a set of reflex actions. It certainly seems, from a physiological point of view, very hazardous to infer — as has been frequently done on philological grounds — the gradual development of the sense of

color in early races of mankind, from the color descriptions of Homer and early Greek writers. It is not an uncommon thing to find children of the lower classes unable to give specific names to the different colors; but, if I am not mistaken, they can always distinguish the primary colors without difficulty, though not able to name them. Certainly, the facility for painting and coloring noticeable in the pottery of the uncivilized races of the world seems unfavorable to this theory.

EXPLANATION OF THE PLATES.

The Plates accompanying this paper are a fair sample of the results to be obtained from the transfer of original drawings by the Heliotype process. The drawings are quite acceptable reproductions of the originals; and this method of illustrating papers on Natural History will prove very useful in many cases. The method described by the younger Sars for obtaining transfers from original drawings is somewhat cumbersome, requiring a great deal of care and a number of processes. The present method simply requires for the naturalist that he should put on thin Bristol board the plate he desires to have transferred, of the size he wishes, and arranged as he desires; the only requisite being that the figures be all drawn with a pen and with a special ink. He may then be assured that he will get a plate nearly as clear as his original; and several transfers being made from the original, — say three or four, — a large number of clear copies can be struck off without reducing the distinction of the impressions, as is invariably the case in all lithographic processes. The delay incident to all lithographic processes requiring a special artist are done away with, and the author has only himself to blame for errors. This method seems to give better results than that employed by Sars. Compare his plates of Brisinga with those of the present paper. The cost of the Heliotype method is moderate; the impression on paper, and whole manipulation, after the drawing is supplied to the patentees of the process, being considerably less than the cost of printing and paper from an ordinary lithographic stone.

Plates III., IV., V., figs. 1–5, illustrate the development of a dextral Flounder, in which the eye passes from the left side to the right side.

Plate V., figs. 6–13, Plate VI., illustrate the development of a sinistral Flounder, in which the eye passes from the right side to the left.

Plate VII. illustrates the development of a sinistral Flounder, in which the eye passes from the right to the left side long before the dorsal, anal, or caudal fins have lost their embryonic character.

Plate VIII. illustrates the changes of color produced in the young Flounders by placing them on differently colored ground.

Plate IX. shows the development of a sinistral Flounder, in which the anterior part of the dorsal becomes to some extent an anterior dorsal.

Plate X. illustrates the passage of the eye through the integuments between the base of the anterior part of the dorsal and the frontal bone.

PLATE III.

Pleuronectes Americanus Walb.

Platessa plana Storer Pl. XXX. fig. 2.

Fig. 1. Young, about 4^{mm} long a few days after hatching. Seen from the left side. The eyes are symmetrically placed at the extremities of an axis at right angles to the longitudinal axis. The pectorals are well developed, the embryonic fin extends unbroken from the base of the brain to the anus, the ventral portion is somewhat broader. The eyes are of a light bright-green, and there are faint yellow patches on the lower sides of notochord along the muscular bands.

„ 2. Somewhat older than fig. 1. The tail has become slightly heterocercal, and the embryo is much less transparent than in the previous stage. The muscular tissue above and below the notochord is of a light-brown color, with yellow patches near the black pigment spots. One or two very indistinct tail-rays have begun to form.

„ 3. In this stage, the principal changes are confined to the increased number of tail fin-rays, and to the segmentation of the vertebral column sending out its dorsal and ventral cartilaginous apophyses. The pigment spots of the embryonic fin-fold (fig. 1), as well as of other parts of the body, seem to become more prominent, when increased activity in the formation of new tissues takes place. See the pigment spots in the tail of this figure.

„ 4. A somewhat more advanced stage, in which the dorsal and ventral embryonic fold has become tolerably separated from the tail-fin. At the base of the dorsal and ventral folds, the basal fin-rays are well developed, but as yet we find no trace of the fin-rays proper.

„ 5. In this stage, the tail-fin is in great part separated from the embryonic fin-fold, which shows here and there traces of the formation of the fin-rays proper; but in other respects it differs from the preceding stage mainly in the greater number of pigment spot patches, in the greater development of the muscular bands, and of the dorsal and ventral apophyses of the vertebral column. The eyes are as yet symmetrical. The length of this embryo is about that of the preceding stage (fig. 4).

PLATE IV.

Pleuronectes Americanus Walb.

Fig. 1. We now come to a series of stages in which the body becomes broader in proportion to the length, and in which the dorsal and anal fins are all gradually isolated from the caudal. In this stage, the fin-rays extend nearly to the edge of the dorsal and anal, the muscular bands are much wider, and there is a slight asymmetry in the position of the left eye, which has moved well forward towards the top of the snout; while in the preceding stages the left barely

extended to point of a vertical passing through the lower extremity of the upper jaw. The patches of color which are to be eventually characteristic of the species first make their appearance in this stage.

Fig. 2. Somewhat more advanced than fig. 1. The left eye, when seen from the right side, projects slightly in advance of the frontal. The dorsal and anal fin-rays are well developed, but still united to the caudal. The tail has become rounded. The patches of coloring are defined. Rudimentary ventral fins have appeared. There are as yet no hard rays in the pectorals.

„ 3. In this stage, the left eye has moved more towards the crest of the snout, the dorsal and anal fins are disconnected from the caudal, and the ventrals are larger than in the preceding stage.

„ 4. More than half the left eye is seen above the frontal ridge; the dorsal and anal still more disconnected from the caudal than in the preceding stage; the ventrals larger, and the pattern of coloration quite marked by prominent pigment cells.

„ 5. In this stage, the left eye has fully passed to the right side, the dorsal fin, extending to the upper edge of the orbit, having gradually extended in that direction from stages represented in Pl. IV. figs. 2, 3, 4. The pattern of coloration of the body and of the fins is like that of the adult, but, of course, more indistinct. The dorsal and anal fins are now completely isolated from the caudal fin: they have both fin-rays fully developed, and have greatly increased in breadth since the last stages figured.

PLATE V.

Figs. 1–5. — Pleuronectes Americanus Walb.

Fig. 1. Head of a young specimen, about in condition of Pl. III. fig. 1. Seen from above, to show the symmetrical portion of the eyes.

„ 2. Head of another specimen, about in the same stage as in fig. 1. Seen from below.

„ 3. Head of a young specimen somewhat more advanced, in which the left eye has changed its position somewhat, and has advanced towards the snout; showing the effect, when seen from above, of the first movement of translation of the eye of the left side.

„ 4. Head of young Flounder, intermediate between figs. 4 and 5, Pl. III., to show the transfer of the left eye above the ridge of the frontal bone.

„ 5. The head of a young Flounder, nearly in the same condition as fig. 4. Seen from the left side, showing the position of the eye during the transfer while projecting above the frontal bone.

Figs. 6–13. — Pseudorhombus maculatus Stein.

Fig. 6. Head of young specimen still in the egg. Seen from above. The eyes symmetrically placed at extremity of a transverse axis at right angles to the longitudinal axis of the Flounder.

Fig. 7. Head of same species, a couple of days after hatching, before any movement of translation or of rotation of either eye has commenced. The two eyes symmetrically placed at the extremities of a transverse axis at right angles to the longitudinal axis of the Flounder.

„ 8. Shows the position of the eyes of the young Flounder from the left side, where the right eye projects beyond the ridge of the frontal bone.

„ 9. Shows the position of the right eye, seen from the right side, at about the time the lower edge of the orbit has reached the summit of the edge of the frontal bone.

„ 10-13. Show in regular succession the gradual passage of the eye from the stage of fig. 9 until it has reached, in fig. 13, the position it retains on the adult entirely on the left side of the body; the space between the eyes separated by the frontal ridge becoming less in each specimen with advancing age.

PLATE VI.

PSEUDORHOMBUS MELANOGASTER STEIN. MASS. FISH REP. 1872, p. 47.

Platessa oblonga Storer Pl. XXXI. fig. 2.

Fig. 1. Young specimen, just hatched from the egg. The yolk mass projecting below the outline of the lower surface; the dorsal embryonic fold much wider than the anal embryonic fin; the pigment spots are confined to the dorsal edge of the brain, and to the muscular band above the notochord.

„ 2. Embryo two days old. The yolk mass projects but little beyond the line of the lower surface. Large prominent pigment spots extend over the whole body, with the exception of a small portion of the tail, which is left bare from the earliest stages (fig. 1), and remains bare for some time yet, thus giving an excellent specific distinction for readily distinguishing the young of this species from other species of embryos about in the same stages. The snout has become more pointed than in the preceding stage, the dorsal embryonic fold has lost much of its width, and in consequence the young fish resembles a tadpole much less than in the preceding stage.

„ 3. Represents the same embryo on the fifth day after hatching. The principal changes consist in the form of the head, the prolongation of the lower jaw well in advance of the upper one, the presence of large pectorals, the increase of the stomach, and a very slight tendency to heterocercality in the tail.

„ 4. Somewhat older embryo. The stomach and alimentary canal have greatly increased in size, the air-bladder has become prominent, the body has greatly increased in width, the tail is decidedly more heterocercal than in the previous stage figured, and the right eye shows a slight tendency to move upward and forward towards the anterior edge of the snout.

Fig. 5. In this stage, considerably larger than the previous one, the change in the outline of the young fish is considerable. The dorsal is highest at its anterior extremity, the caudal is well separated from the dorsal and anal fins, in all the fin-rays are fully formed, the profile of the head is more blunt, and the whole body thickly covered with dark pigment cells.

„ 6. The differences of this stage from the younger one (fig. 5) consist mainly in the greater width of anterior part of the body; the distinct pattern of coloration; the increase in width of the dorsal and anal fins, and their disconnection from the caudal, which has become elongated and rounded at the extremity; the presence of small ventrals; and the transfer of the right eye forward and upward, so that one half is visible above the frontal from the left side.

„ 7. Is a young Flounder, taken late in the season, but slightly larger than fig. 6, in which, however, the right eye has passed well over to the left side. The dorsal has extended towards the posterior edge of the right eye, its anterior edge projecting over the eye. The pattern of coloration is similar, in a general way, to that of the adult, and extends into the base of the broad dorsal and anal fins. The ventrals are larger than in fig. 1. The Flounder in this stage and the preceding stages (figs. 4, 5) habitually rests on the right side, but as yet none of these young fishes show any difference in the coloration of the right from the left; the former being still quite as brilliant as the latter in the oldest stage here figured (fig. 6).

PLATE VII.

Rhombus maculatus Mitch.

Pleuronectes maculatus Storer Pl. XXXI. fig. 4.

Fig. 1. Young specimen, with rudimentary air-bladder, few pigment spots, measuring 5^{mm} in length.

„ 2. Somewhat more advanced than fig. 1. The pigment spots greatly developed, but the embryonic dorsal and anal fins show scarcely any advance.

„ 3. The body has become somewhat broader, the tail far more heterocercal, and rudimentary fin-rays appear both in the dorsal and anal fins. Patches of coloring indicating the future pattern are well defined.

„ 4. Somewhat more advanced, but slightly longer, than fig. 3. The base of the fin-rays of the dorsal and anal are well developed. The body, with the exception of a bare space of the tail and adjoining part of the body, is of a uniform grayish-brown color, with patches of yellow, and black longitudinal lines along the upper and lower edges of the notochord, and the base of the dorsal and anal fin-rays, as well as following the muscular bands along the ventral edge. The upper and posterior edge of the stomach is covered by intensely black pigment spots closely crowded together.

Fig. 5. Slightly older than the preceding stage. The eye, from the right side, projects above the line of the snout; the coloring much as in fig. 4. The anal, dorsal, and caudal fins are, however, more advanced.

PLATE VIII.

Rhombus maculatus Mitch.

Fig. 1. Young sinistral Flounder, natural size, showing the color assumed when the fish is placed upon a dark mud-colored ground.

„ 2. The same fish, somewhat enlarged, showing the coloring assumed when placed upon a yellowish sandy soil.

„ 3. Another specimen of the same species, somewhat younger than the preceding stages, showing the coloring assumed when placed upon a mottled ground (partly gravel, partly sand) somewhat darker than the yellowish sandy soil.

„ 4. Black pigment spots forming the blotches along the lines of the rays of the dorsal, when fully expanded.

„ 5. Another portion of the dorsal, showing the spots when contracted.

„ 6. A portion of the pigment spots of the colored side, showing the red, the yellow, and the black pigment spots when fully expanded, the darker tints between the colored pigments representing the masses of iridocytes.

PLATE IX.

Pseudorhombus oblongus Stein.

Platessa quadrocellata Storer Pl. XXXI. fig. 3.

Fig. 1. Egg of Flounder, showing the symmetrical head of embryo.

„ 2. Head of young Flounder, the fourth day after hatching. Seen from above.

„ 3. Head of fig. 4. Seen from below.

„ 4. Young Flounder. Seen in profile. Quite transparent. Remarkable for the great development of the dorsal embryonic fin, 6.5^{mm} in length.

„ 5. Somewhat older than fig. 3. First trace of heterocercal tail.

„ 6. Older than fig. 4. The anterior part of the dorsal is developed before the rest, forming a sort of anterior dorsal. The eyes are still symmetrical.

„ 7. Young Flounder, quite well advanced. The fins are all differentiated. The right eye has, however, moved, thus far, but little forward and upward.

PLATE X.

Plagusia Sp.

Fig. 1. Young Plagusia, slightly over an inch long. Seen in profile. The eyes of the two sides are equally distant from the snout: they are placed symmetrically with reference to a longitudinal axis, and a plane

passing through the transverse axis. This specimen is perfectly transparent, — fully as transparent as the most delicate Hydroid Medusa. The action of the heart, the course of the vessels, can be readily followed, as well as the other structural details, which are usually only visible after dissection. The dorsal fin projects far down the frontal ridge to the nostrils, well in advance of the eyes.

Fig. 2. Young Plagusia (fig. 1). Seen with head on.

„ 3. Shows the relative position of the eyes after the first movements of translation and of rotation have become visible by the slight advance and rising of the eye of the right side. Seen from the left side.

„ 4. Somewhat more advanced than fig. 2. Seen from the right side. The outline of left eye can be traced through the tissues of the head.

„ 5. Head, seen from the left side. The right eye has moved upwards sufficiently to be seen through the tissues of the head, clear above the left eye. We find in this stage the first trace of the opening of the eye on the left. The eye, when turned in the socket, can look through the tissues at the base of the dorsal; and, when thus turned, to see through the left, is nearly as sensitive to approaching objects as the left eye. When looking at the same fish for the other side (the right), we find that the eye has deeply sunk in the tissues between the frontal bone and base of dorsal fin, and that, while sinking and pushing its way to the opposite side, the tissues of the right side have gradually united and narrowed the former large circular orbit to a mere small elliptical opening.

„ 6. The eye of the right side, as turned to the right; the new orbit appearing on the upper edge of the eyeball.

„ 7. The same eye with the ball turned toward the left, showing the commencement of the new orbit forming as a small circular opening on the left side of the fish. The old orbit of the right side being now reduced to a minimum, the fish now having two orbits on the left side and one on the right. The orbit of the right being reduced to a small aperture, and disappearing in a subsequent stage (fig. 9), while the new orbit of the right eye on the left side is as yet much smaller than the corresponding orbit of the left eye.

„ 8. Head seen from the right side, showing the small size of the old orbit of the right eye after it has forced its way partly across the head.

„ 9. The right eye has now passed entirely round the frontal bone, and is held in its hollow curve, and has at same time forced its way through the tissues so far that the original orbit of the right side has become closed, and the new orbit for the right eye on the left side has become nearly as large as the orbit of the left eye.

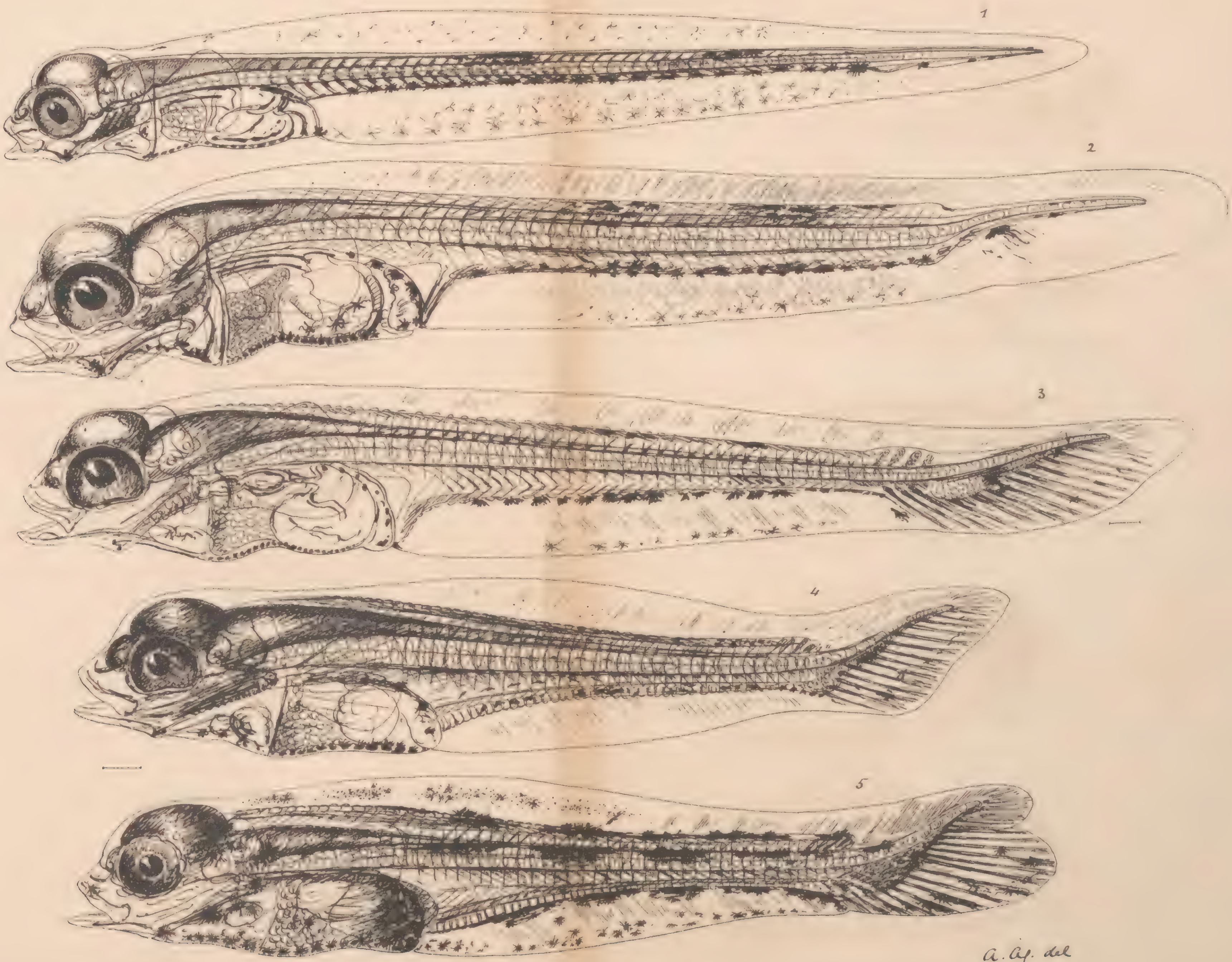
„ 10. In this stage, the eye from the right side is now completely transferred to the left, and no difference is apparent between the orbits. In this and all preceding stages, the great length of the two optic nerves is readily seen; and we thus understand the possibility of so extensive a movement of either eye without interfering with the visual function. The slack of the optic nerves being only taken in for the eye which happens to be transferred in any genus of Flounder.

There is in Flounders a most active circulation going directly from the heart to the orbits and back again: this is well shown in this figure by the direction of the arrows along the vessels leading towards the orbits and back again to the heart.

Fig. 11. Is a young Plagusia, after the transfer of the eye, nearly three inches long, showing even at this stage but a slight accumulation of pigment spots along the dorsal and anal fins parallel to the line of the spines. A few yellowish and black pigment spots have also accumulated on the left side, but the young fish has as yet lost but little of its transparency.

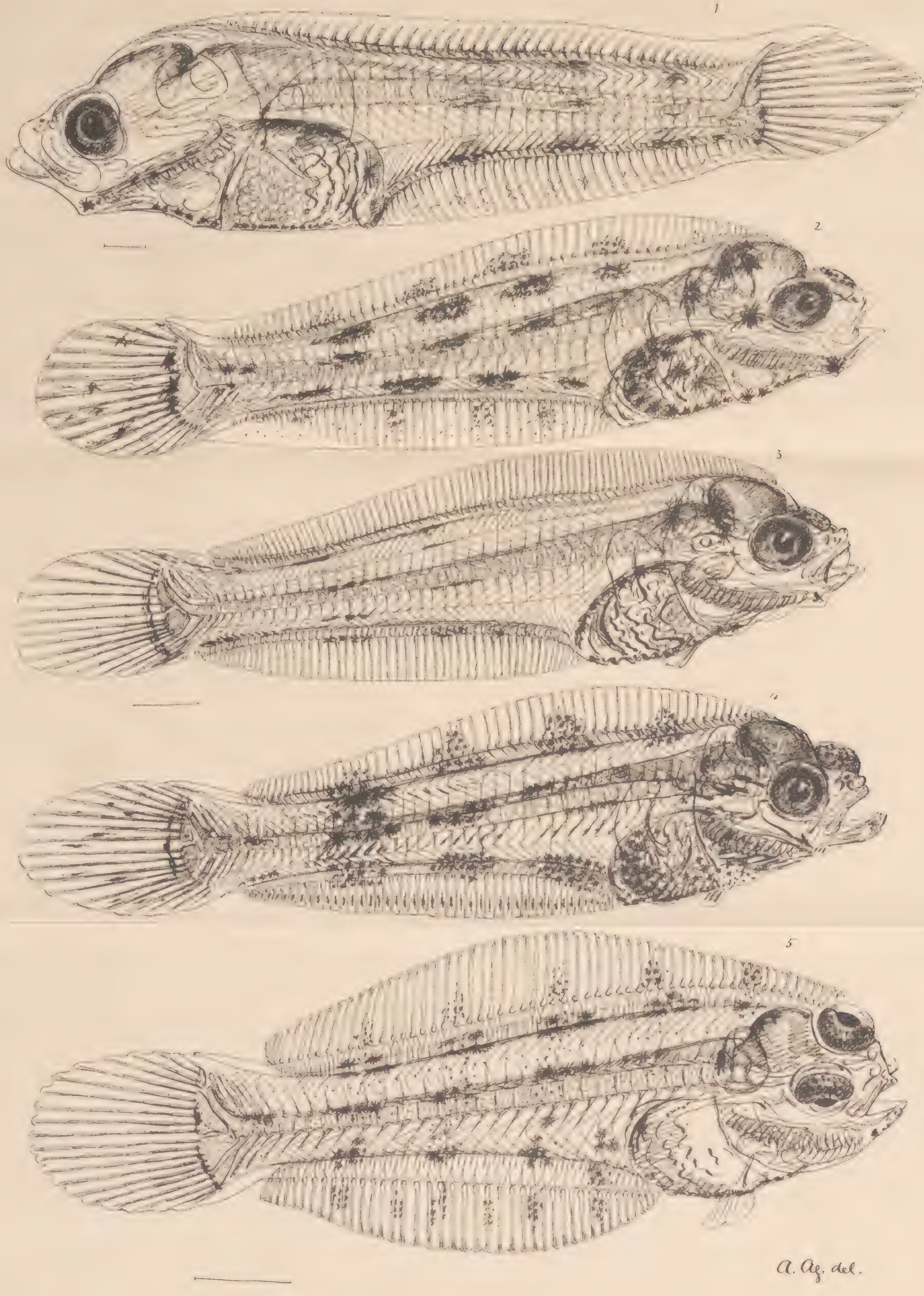
What eventually becomes of this species I am not able to say, and it is not improbable that this species is identical with that described by Steenstrup, and it may also be the young of the Plagusia found on the Atlantic coast of the Southern States.

Alex. Agassiz Young Fishes Pl. III



A. Ag. del

Alex Agassiz Young Fishes Pl IV

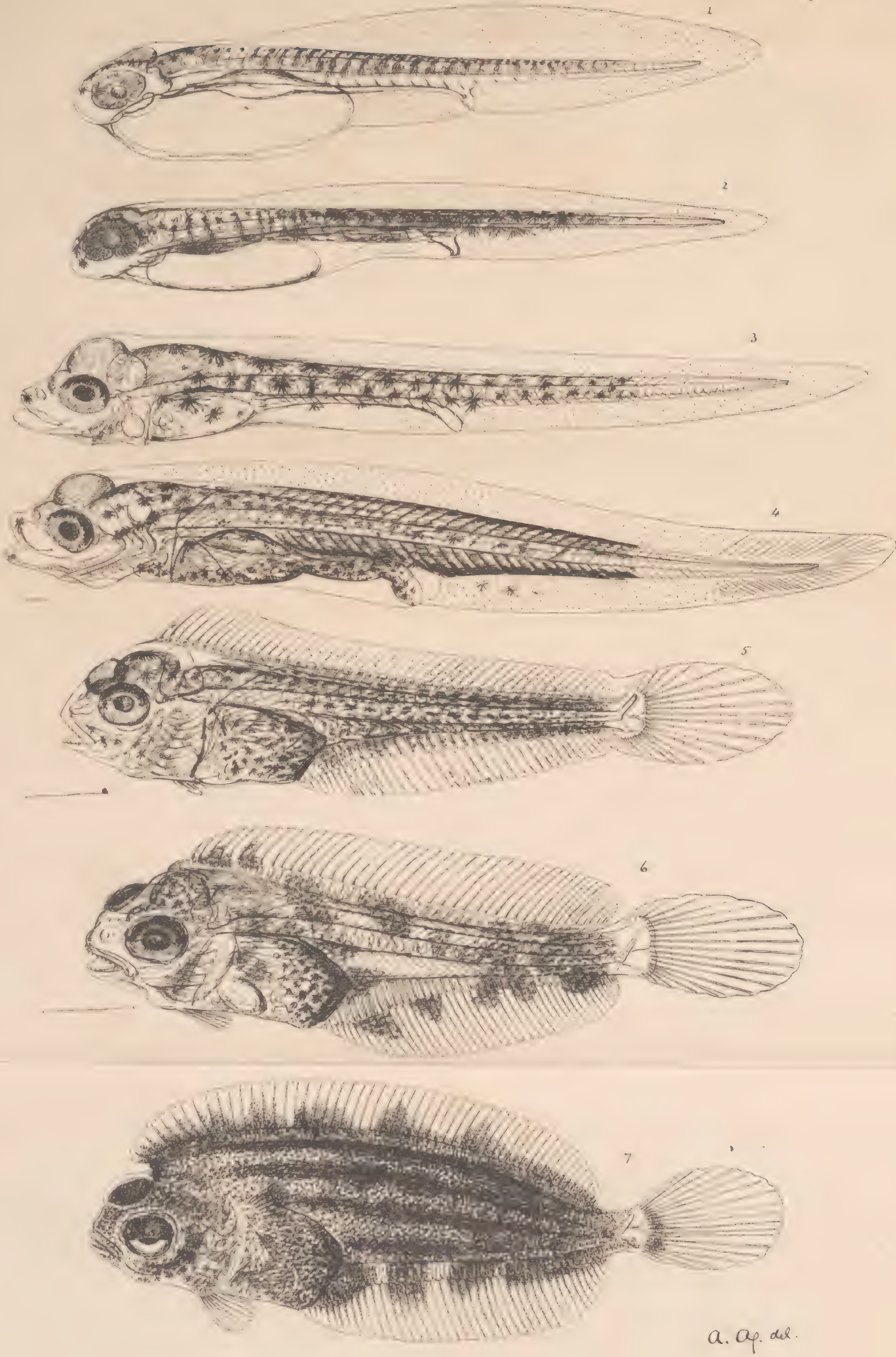


A. Ag. del.

Alex. Agassiz 'Young Fishes' Pl. I

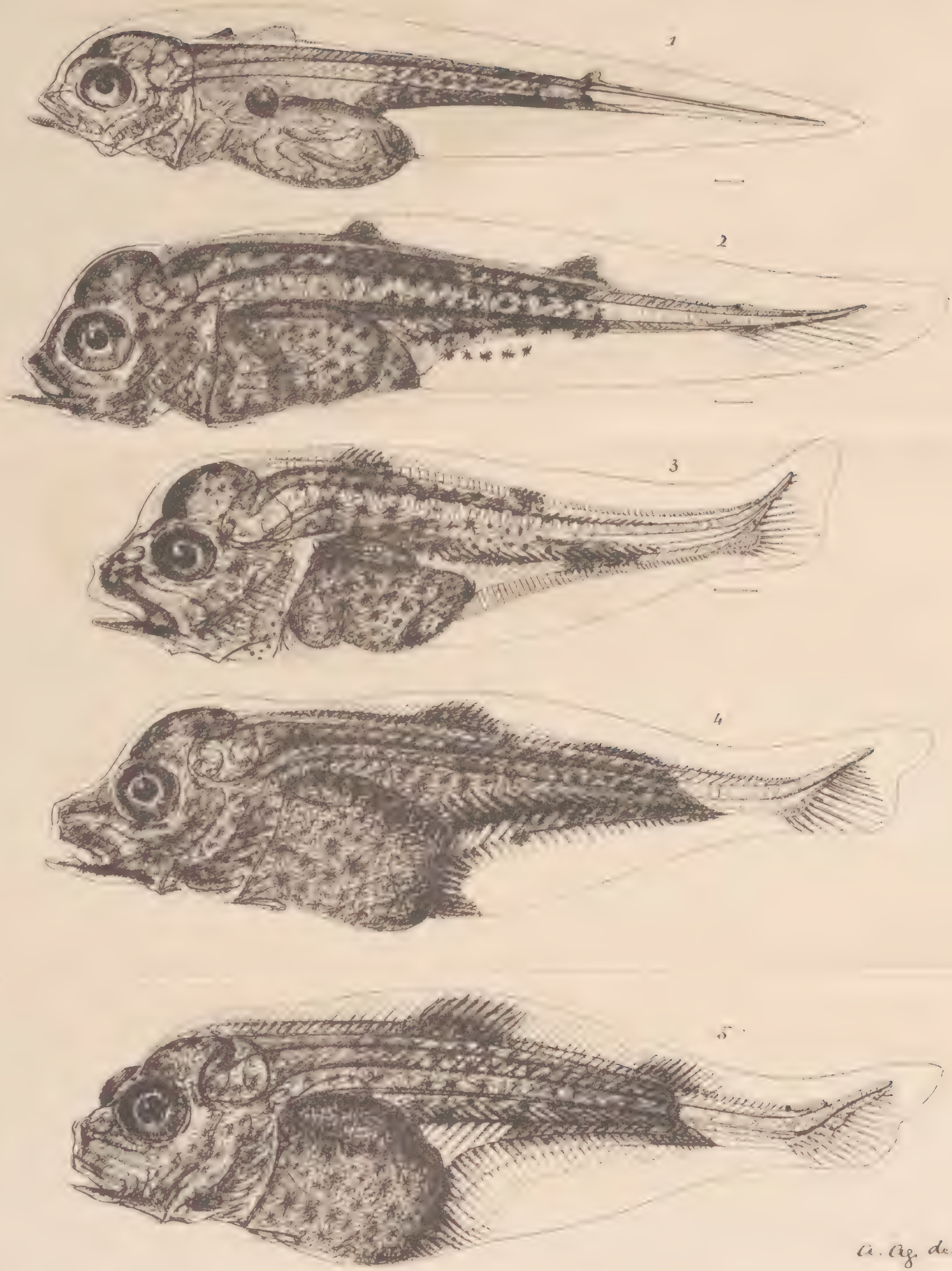
A. Ag. del.

Alex. Agassiz Young Fishes Pl. VI



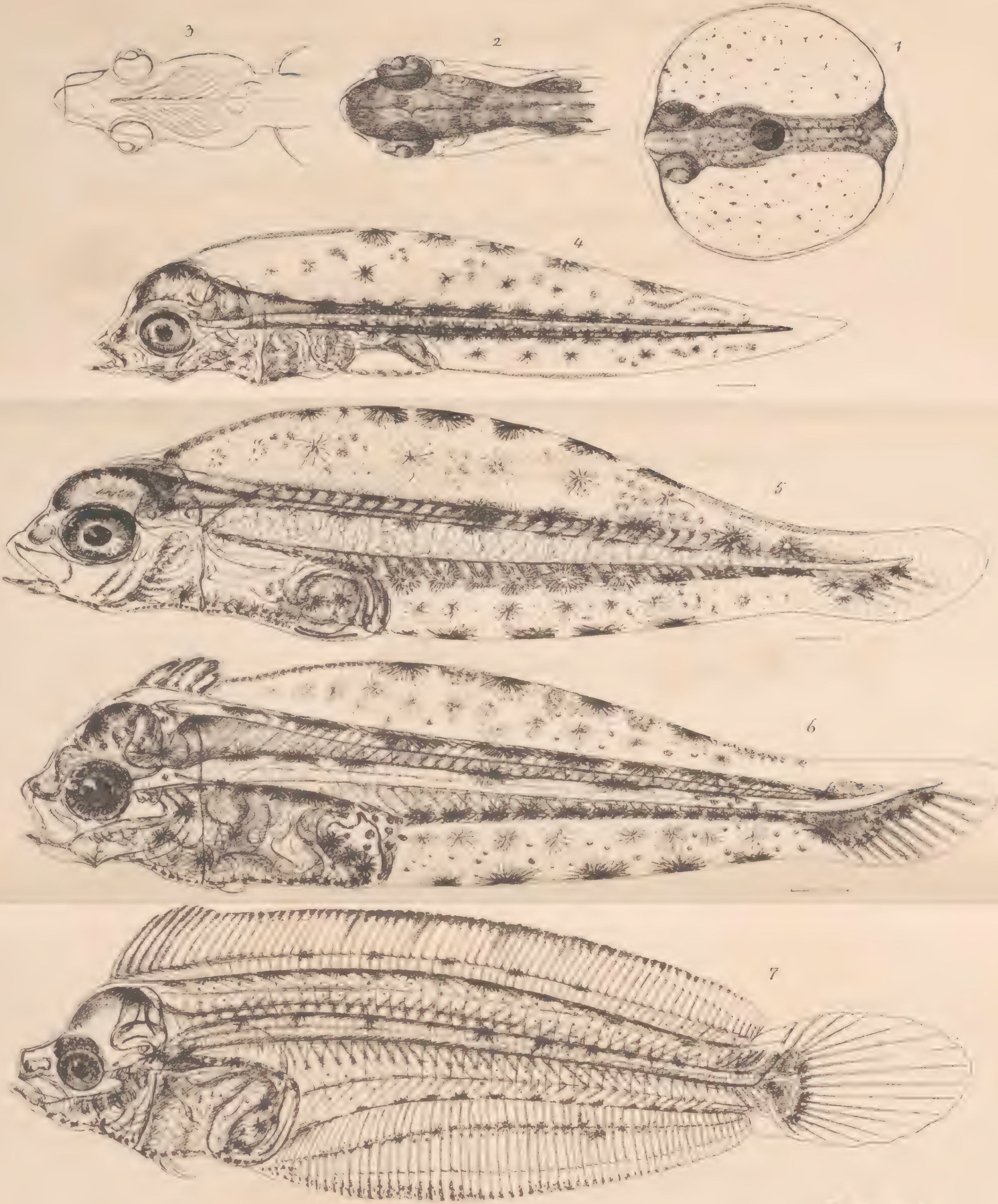
A. Ag. del.

Alex. Agassiz Young Fishes Pl. VII



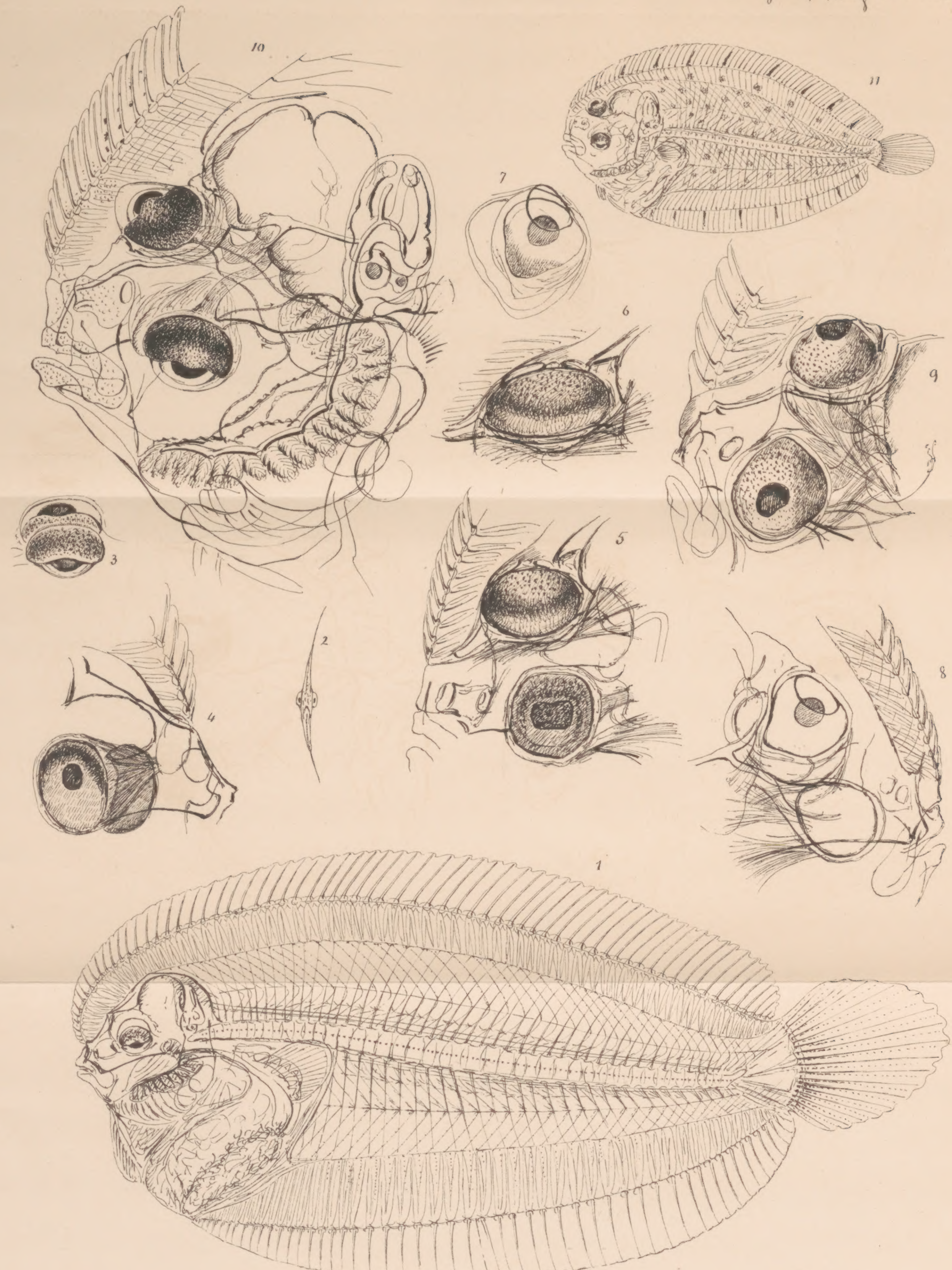
A. Ag. del.

Alex. Agassiz Young Fishes Pl. IX



A. Ag. del.

Alex. Agassiz Young Fishes Pl. X



A. Ag. del.